INAUGURAL AUSTRALIAN NATIONAL PHYSICS COMPETITION

THEORY EXAM

Wednesday December 3, 2:00 pm, RSPHYSSE, ANU

SAMPLE QUESTIONS

Problem 1. *(1 mark)*

A small mass begins to slide from the top of a sphere, which is held fixed. The sphere has radius $R = 1.5$ *metres. Find the height* h *in metres above the level of the centre of the sphere that the mass leaves the sphere and flies through the air. Neglect friction and give you answer to* 2 *significant figures.*

Problem 2. *(1 mark)*

Find the acceleration given to one electron by another when they are separated by a distance of $r = 1.0\,mm$*. Give your answer to 2 signifcant figures in units of* ms^{-2}*.*

Problem 3. *(2 marks)*

Using the Bohr model of the atom calculate to 2 significant figures in Tesla the magnitude of the magnetic field $\mathbf{B}$ *at the centre of the Hydrogen atom caused the electron in the ground state.*

Problem 4. *(2 marks)*

The apex angle of a prism with refractive index $n = 1.20$ *is very small,* $\theta = 2.0$ *degrees. Calculate the angular deviation of a light ray passing through this prism to 1 significant figure in degrees.*

Problem 5. *(3 marks)*

A spherical asteroid of uniform density $\rho = 2.0 \times 10^3\,kgm^{-3}$ *and of radius* $A = 1.0 \times 10^4$ *metres has a small spherical cavity of radius* $R = 50.0$ *metres at a centre-to-centre distance of* $\lambda = 4.0 \times 10^3$ *metres. A particle is released from rest from the centre of the cavity. Find the time taken to reach the edge of the cavity to 2 significant figures in seconds.*

Problem 6. *(3 marks)*

A cylindrical capacitor has inner radius $R_i = 2.0\,cm$ *and outer radius* $R_o = 2.001\,cm$. *The original dielectric is air. A constant voltage of* $10\,Volts$ *is applied across the plates and a new dielectric with relative permittivity* $\epsilon_r = 5.0$ *is inserted between the plates so as to fill the space between them totally. Calculate the magnitude of the force on the dielectric to 1 significant figure in Newtons.*

Problem 7. *(4 marks)*

A quantum particle of 5 *electron masses in one dimension sits in the usual infinite potential well given by* $U(x) = 0$ *if* $|x| < l/2$ *and* $U(x) = \infty$ *elsewhere, where* $l = 5.0$ *Angstroms. Using 1st order perturbation theory calculate the change in the ground state energy of such a particle if the potential is perturbed by the addition of another potential of the form* $U_p(x) = 0$ *for* $|x| > \lambda/2$ *and* $U_p(x) = \epsilon$ *for* $|x| < \lambda/2$, *where* $\epsilon = 1.0\,eV$ *and* $\lambda = 1.0$ *Angstroms. Give your answer to 1 significant figure in eV.*

Problem 8. *(5 marks)*

Two plane perfectly smooth mirrors touch with an angle $\gamma = 1.3\,degrees$ *between them . An incoming light ray makes an initial angle of* $\theta_1 = 10.0\,degrees$ *with one of the mirrors. To two significant figures find the number of reflections suffered by the ray before it escapes. You may assume that geometrical optics always holds in this case.*

Problem 9. *(7 marks)*

A particle with kinetic energy $1.5\,MeV$ *collides with a spherically symmetric potential centered on the origin and of the form* $U(r) = 0$ *for* $r > R$ *and* $U(r) = -U_0$ *for* $r < R$ *where* $U_0 = 2.0\,Mev$ *and* $R = 5.0$ *Angstroms. Here r is the distance from the origin. The particle has an initial trajectory along a line D. It has has an impact parameter* $b = 2.0$ *Angstroms , where b is defined as the perpendicular distance from the origin to the line D when the particle is a long way from the potential well. Calculate to 2 significant figures, in degrees, the angular deviation of the particle from D after the collision with the potential. Do this problem using classical mechanics - no quantum mechanics or relativity.*

Problem 10. *(7 marks)*

An endless flexible and inextensible chain in which the mass per unit length is $\mu = 5.0\,kg/m$ *through one continuous half and* $\mu' = 2.5kg/metre$ *through the other half is stretched over two equal uniform circular discs of radius* $a = 0.10\,metre$ *and mass* $10.0\,kg$ *each. The discs can turn freely about their centres at a distance* $b = 0.75\,metres$ *in the same vertical line. Find the period of small oscillations of the chain under the action of gravity to 1 significant figure. You may assume that the discs are "rough" so that the chain never slips on them. Give your answer in seconds. (Taken from Cambridge University, Mathematical Tripos Examination, Tuesday January 19, 1875, 1:30 pm to 4:00 pm.)*